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PORTABLE CONTAINERS FOR TRANSPORTING EXPLOSIVES BY AIR, SEA AND LAND

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MICROMEDIA

INTRODUCTION

The explosive Technology Unit (ETU) of the RCMP requires a container that will allow safe transportation of blasting caps and explosives. Due to the nature of the ETU's work, it is necessary to transport the explosives by air, sea and land. If it is necessary for the transportation to be by air it will only involve a private aircraft whereas if it is by sea, commercial vessels may be involved. On land, the container is normally shipped by RCMP's vehicles with authorized drivers.

The process of transport subjects explosives to several potentially dangerous situations. The most obvious of these is the collision of the transport vehicle. This action involves low velocity impacts. Also, since most vehicles are propelled by combustible fuels, the risk of a fire is always present. Therefore in such a situation, explosives must be guarded against impacts and high temperatures. If the action of impact does not cause the explosive to detonate, then the explosive should have sufficient fire protection that would allow personnel evacuation from the vicinity of the danger zone. An additional requirement exists if blasting caps are being transported with explosives. If the blasting caps were caused to detonate, then the explosion should not communicate to the high explosives.

In the case involving a reusable explosives' magazine, the container must be light so that it can be safely handled and it must be able to withstand the abuses associated with transportation. The portable magazine must also have a certain degree of security.

This report presents results obtained in designing and recommending a portable magazine to be used for transporting 2.5 kg of explosives and ten blasting caps. Based on the above discussion, the magazine must protect the explosives in the following manner.

1. The explosives must be protected from the physical abuse that may occur during transportation.

2. When the magazine is caught in a fire it must protect the explosives from detonating for a minimum period of one hour.
3. If, for any reason, a blasting cap detonates, the magazine must be so designed as to prevent the initiation of the explosives and if possible to prevent the initiation of the other blasting caps.
4. The total mass of the magazine with contents should not be more than 50 kg.

The study began by identifying and evaluating the materials that would be appropriate for fabricating the container and finally constructing and testing prototype magazines.

FIRE TEST

The burning trials on the proposed magazines were all done in the facilities shown in Fig. 1. A steel tank 2 m in diameter, 2 m long and having a wall thickness of 2.5 cm is surrounded by 25 cm of reinforced concrete and is on its side in an earth mound. In the tank is a steel grating on which the sample being tested is placed. Wood to fuel the fire is placed underneath the grating and on either side of the sample as shown in Fig. 2. Since the fire must be maintained for at least one hour and since it cannot be approached to add more wood, an 8 mm copper pipe is used to deliver diesel fuel to the fire. The fuel is pumped from the control building to a steel pan placed under the grating in the tank. Thus, whenever the fire temperature drops, fuel is pumped so as to reestablish the previous temperature. Thermocouples are used to monitor the fire temperature at the grating just below the sample and to monitor the temperature at any other point in the sample. The fire is also viewed remotely via a television monitor inside the control building.

This set-up was found to work very well. There was no problem keeping the fire burning for a period of two to three hours and the tank retained enough heat that no effect was detected from the changing ambient conditions. It was

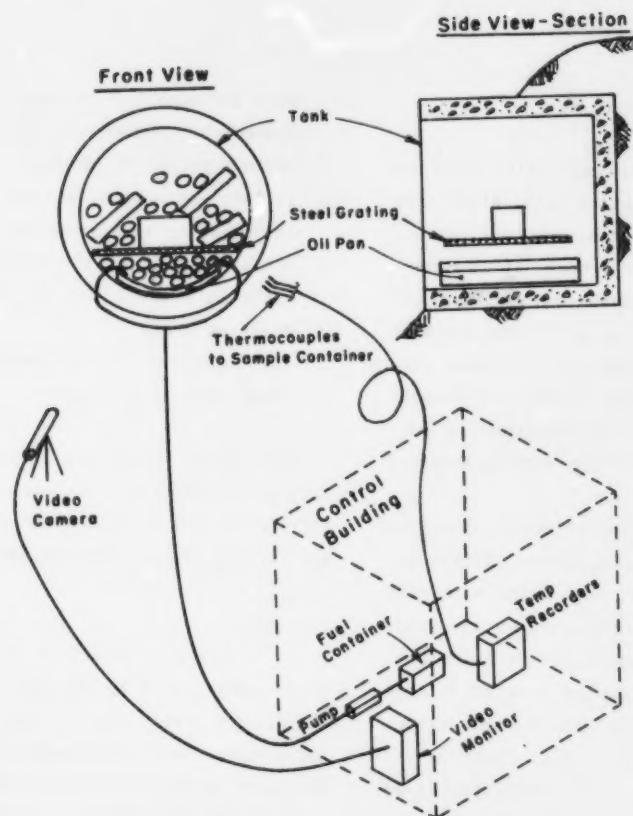


Fig. 1 - Fire test facilities

found that the best thermocouples were the shielded type. The first used in this work was a K-type with a 304 stainless steel sheath. This is an austenitic stainless and is meant for general use. However, it was found that during the test a reaction took place between this stainless steel and the aluminum on the magazine being tested. The result was a molten sheath at the reaction site. This could easily cause short circuiting of the thermocouple and so it was decided to change to a different sheath material. The one chosen was Inconel. This metal is suited for severely corrosive environments at elevated temperatures and has high hot-strength and resistance to progressive oxidation and fatigue. No problems arose through the use of this type of material, however even it showed signs of reaction with aluminum. The temperature was recorded using strip-chart recorders and digital printers.



Fig. 2 - Sample container in fire test

PORTABLE CONTAINERS FOR TRANSPORTING EXPLOSIVES
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ABSTRACT

Several containers to be used in shipping explosives and blasting caps by sea, land or air were designed, built and tested. The specific tests that the containers were subjected to were a fire test and a communication test between the blasting caps and explosives. It was found that a commercially available vault with a minimum of modification best suited the purpose.

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CONTENANTS PORTATIFS POUR LE TRANSPORT D'EXPLOSIFS
PAR AIR, MER ET TERRE

par

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RÉSUMÉ

De nombreux contenants à être employés pour l'expédition d'explosifs, et de tétonateurs, par mer, terre et air ont été créés, fabriqués et éprouvés. L'essai du feu et celui de la communication entre les détonateurs et les explosifs constituèrent les essais spécifiques auxquels furent soumis les contenants. Il s'est avéré qu'un coffre-fort disponible sur le marché et auquel on apporta quelques changements mineurs, était ce qui répondait le mieux au besoin en cause.

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EVALUATION OF MATERIALS

Materials used in the construction of the magazine fall basically in two categories. The two categories distinguish between the materials used on the inside and the materials used on the outside. Materials used on the inside of the magazine must be light, non-combustible and, if possible, good attenuators of shock waves. Those materials used on the outside must be physically strong so as to withstand abuse and to rigidly maintain the form of the inside material.

From previous work it is already known that vermiculite, glass fibre board, foam, and pressed paper board are materials that have been found useful in preventing communication from blasting cap to blasting cap (1,2). However, certain problems have arisen in the use of such materials.

Vermiculite requires a container that will conform the vermiculite to the required shape. This is awkward and adds mass to the container. Foam and pressed paper board can be manufactured to required shapes, however as with the vermiculite, they have another disadvantage. Under high temperatures as encountered in a wood fire, a foam container such as that shown in Fig. 3 would decompose so as to allow the blasting caps to collapse and make physical contact with one another. Then if one was to initiate, it would easily communicate to the others. Pressed paper board which has also been used to form a container similar to that of foam by gluing layers

of the board together will also effectively stop communication to other blasting caps if one of them detonates. This container, however, has an additional disadvantage besides the fact that it may combust at high temperatures. It has been found that even though a detonating blasting cap will not communicate to the rest, the explosion may cause the paper board to ignite and burn, eventually causing the other blasting caps to detonate. The same situation will present itself if the container holding the vermiculite is made of combustible material. In a fire this material will burn. The vermiculite and blasting caps will collapse. Exposed to the fire, the blasting caps can easily explode and communicate to one another.

Glass fibre board was found to be an appropriate material, however, because of its structure, it requires that the holes be lined with a material that would prevent wear when removing and inserting blasting caps in the holes on the block. This is shown in Fig. 4. Another disadvantage found with this material is that in a fire, the binder melts and the glass fibres collapse thereby losing its insulating value. Eventually, at higher temperatures the glass fibre itself melts. The next section describes the use and results obtained with this material when used in the manufacture of an explosives' magazine.

Other materials that were considered were foamed glass, asbestos-free cement and calcium silicate. Foamed glass has a high insulating value, a low density and is easily worked into the

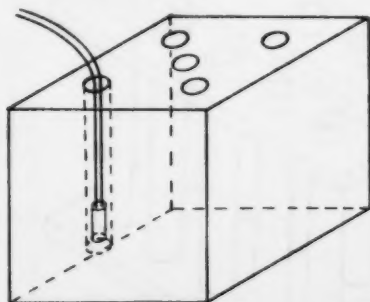


Fig. 3 - Foam blasting cap container

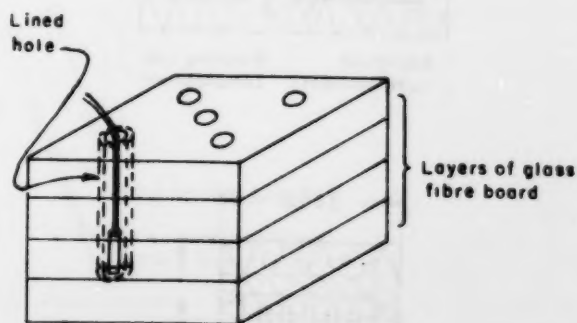


Fig. 4 - Glass fibre board blasting cap container

required shape, however, it is very brittle and melts in a wood fire. A block of the foamed glass containing an electric blasting cap lasted only a few seconds in a wood fire.

a) Evaluating Glass Fibre Insulation

The magazine shown in Fig. 5 was prepared using rigid glass fibre insulation and aluminum. Basically, the container was made from two aluminum boxes welded together with each having its own lid and lock. The large explosives' compartment was lined with 5 cm of rigid glass fibre insulation and an inner aluminum container. Two aluminum trays were placed in the inside container and an aluminum lid with 2.5 cm of insulation was used to seal the inner container. The lid for the outside container was lined with 5 cm of insulation and made a tight seal when closed. The smaller blasting cap compartment was also lined with 5 cm of the rigid glass fibre insulation, had an inner

aluminum container and an inner and outer insulated aluminum lid. Inside the inner box was placed the item shown in Fig. 6. It was meant to prevent communication among the blasting caps. Each blasting cap holder was made from 2 cm diameter, 15 cm long aluminum rod having a 10 cm deep hole with all being held together by aluminum plates. The assembly contained ten aluminum holders with five having a 1.2 cm diameter hole and the other five having a 1.0 cm diameter hole. This blasting cap holder was being tested since the aluminum would be longer wearing than any other insulating material. In order to test this magazine, five electric and five non-electric blasting caps were placed in each assembly. In the large compartment three different explosives were placed in the trays. Thirty cm of detonating cord and a 2) cm by 3 mm thick piece of sheet explosive (63% PSTN) were placed on one tray and 200 g of Composition C-4 were placed in the other tray. With two blasting caps (one from each of the different size cap holders) connected to a firing box and both lids secured with clasps, the two blasting caps were detonated. On observing the magazine, it was

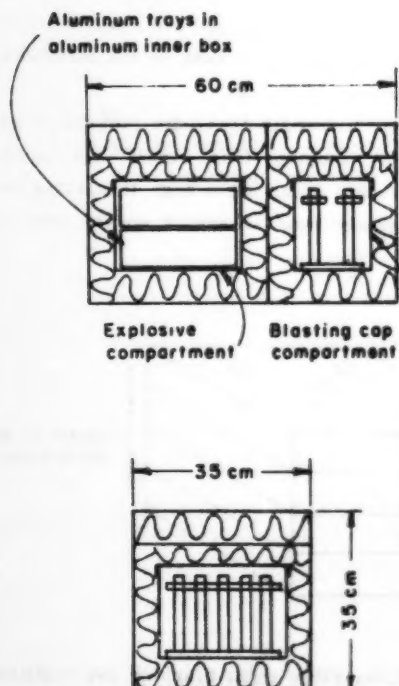


Fig. 5 - Aluminum container with glass fibre insulation

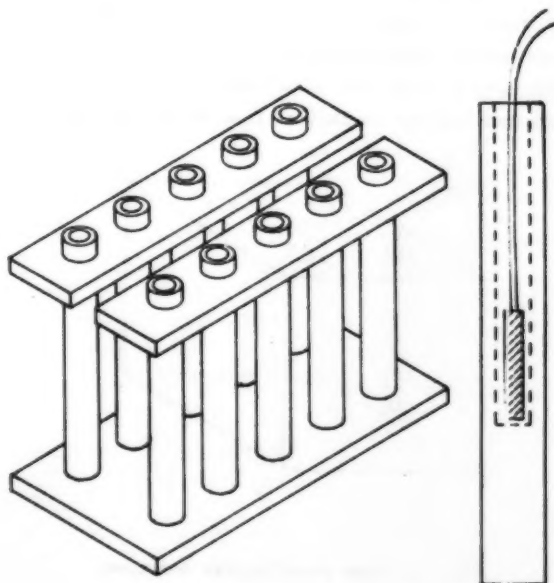


Fig. 6 - Aluminum blasting cap holder

found that the large compartment was not affected by the blast. However, there was damage to the smaller compartment. The two blasting cap holders in which the detonators had been fired were damaged and the bottom of the aluminum inner container had been perforated. The force of the blast had also caused damage to the insulation and one of the welded seams of the outside container.

This magazine was then subjected to a fire, the results of which are shown in Fig. 7. As noted in the figure, all the blasting caps detonated within the first fourteen minutes. These early fires were due to the damaged insulation and the tear on the outside container. The explosives did not detonate, however, there is an indication of their burning as detected by the higher temperatures recorded by the thermocouple TC-3. The magazine was totally destroyed by the fire. The

outside aluminum box melted, the glass fibre insulation fell apart and melted, and the inner aluminum boxes and trays also melted. No trace of the explosives was found.

b) Evaluating Asbestos-Free Cement

Asbestos-free cement is purchased in powder form. By adding water it can be shaped around objects such as pipe elbows so as to provide an insulating layer. Once cured, the cement was found to have a density of about 0.9 g/cc. In order to evaluate this material, several samples were prepared as follows:

- a) In the bottom of a 500 g tin coffee can was placed one electric blasting cap and 15 cm length of detonating cord. The plastic lid was placed on the tin container and a thermocouple was inserted through it so as to detect

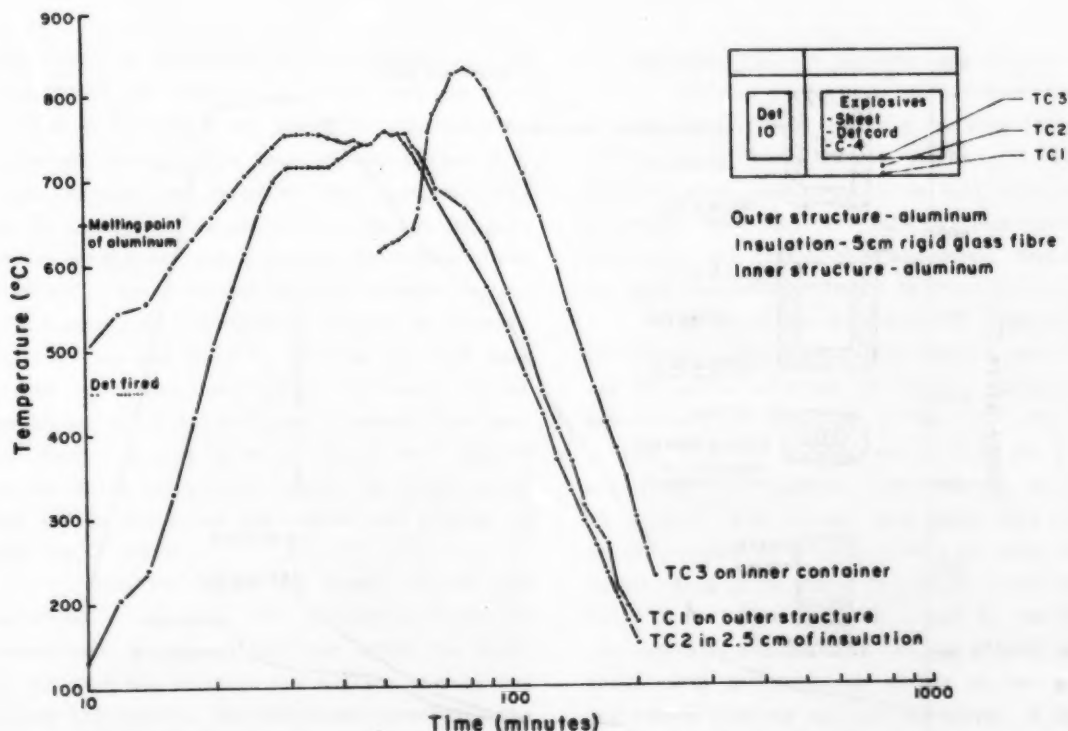


Fig. 7 - Temperature profiles from fire test on aluminum container with glass fibre insulation

the inside temperature. A 1.2 cm thick coat of cement was then molded all over the container surface.

- b) A tin can as the one above with the same contents but with a cement layer 1.8 cm thick.
- c) A tin can as above containing one electric blasting cap but having no coating or thermocouple.
- d) One electric blasting cap coated with 2.5 cm of cement.

The above four samples were placed on the grating and subjected to the temperature profile shown in Fig. 8. The blasting cap in the uncoated can detonated first 1.2 minutes after the start of the fire. The next to detonate was the explosive in the can coated with 1.2 cm of cement. It exploded at 32.3 minutes. Sample b) exploded next at 44.6 minutes and sample d) with a 2.5 cm coat of cement

exploded last at 49.8 minutes. From the way that the cans had been perforated it was indicative that only the blasting caps had exploded while the detonating cord had merely burned.

In order to best evaluate this material it was decided to form it in the shape of a box. A box 40 cm by 40 cm by 45 cm high was fabricated from 3 mm thick aluminum. A second box made from 1.5 mm thick steel was made so that it would fit inside the aluminum one leaving a 5 cm gap between each other. That is, the dimensions of the steel box were 30 cm by 30 cm by 35 cm high. This gap was filled with cement as shown in Fig. 9. With a cement thickness of 5 cm it was decided to reinforce the cement with wire mesh. The construction of the container progressed as follows.

On the bottom of the aluminum box was placed a 2.5 cm thick layer of cement, a piece of

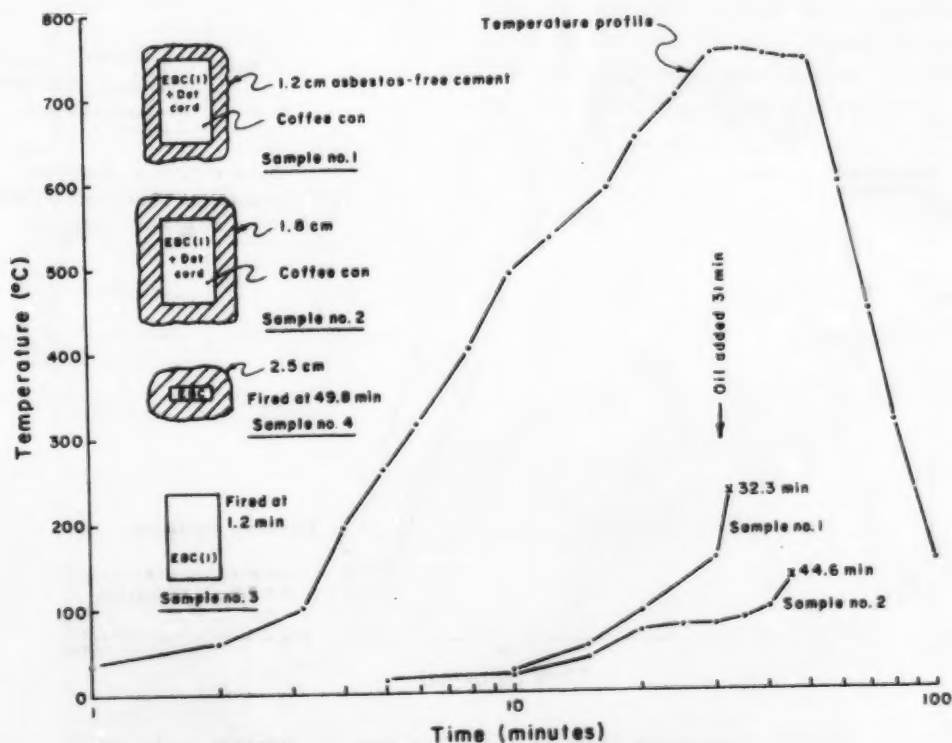


Fig. 8 - Temperature profiles from fire test on metal cans coated with asbestos-free cement

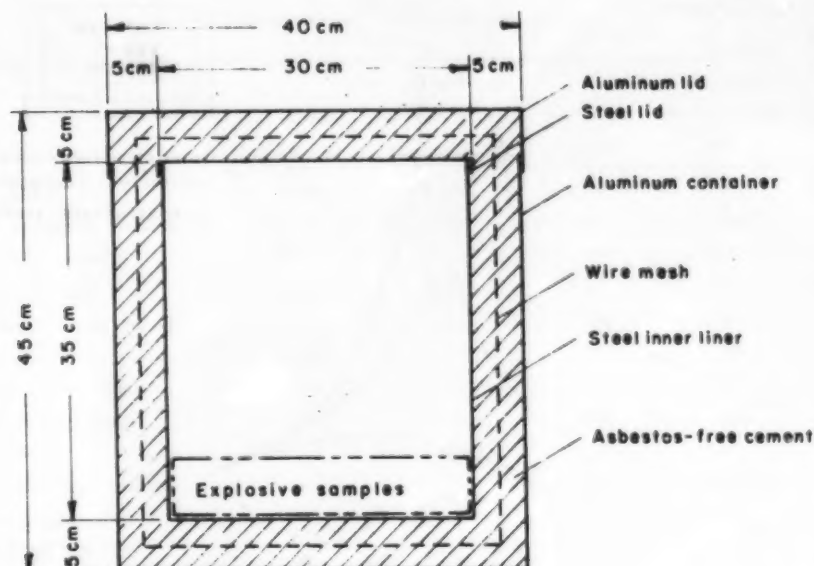


Fig. 9 - Structure of container made with asbestos-free insulation

wire mesh, a thermocouple, and another 2.5 cm thick layer of cement. The steel box was then centred on the cement and inside the aluminum box. As on the bottom, wire mesh was sandwiched with cement between the steel and the aluminum sides of the boxes. A hole was drilled through the sides of both boxes and a second thermocouple was cemented in place so that it would measure the inside temperature. Three 30 cm lengths of detonating cord and one electric blasting cap were then placed inside the steel box and the steel lid was put in place. A 2.5 cm layer of cement, wire mesh and another 2.5 cm layer of cement were applied on top of the steel lid. Finally the aluminum lid was put in place and the cement was allowed to cure for 24 hours.

Once the cement had cured, the box was subjected to the fire test. Figure 10 shows the temperature profiles. One hour after the start of the fire the aluminum box melted, thereby exposing the cement. No explosions occurred. The next day, the cement container was carefully cut open, and as can be seen from Fig. 11 the explosives were intact and the cement was structurally sound.

c) Evaluating Calcium Silicate

Calcium silicate is widely used for insulating water pipes, and in plate form it can be easily cut to the required shapes. It absorbs physical shock and in so doing will only deform slightly. When subjected to high temperatures it embrittles and fine cracks may form. Properties for this substance are found in Table 1.

In order to determine if communication would occur among the blasting caps if one of them was detonated, a block of calcium silicate was manufactured as detailed in Fig. 12. The block is made from two pieces, each 7.5 cm thick that are glued (3) together. The overall size was 15 cm by 15 cm by 15 cm. Five holes were drilled in the pattern shown with each hole being 9.5 mm diameter and 11 cm deep. The edges of the outside holes were 3.5 cm from the sides of the block. One high-strength blasting cap was placed in each hole. With the container placed on the ground, the centre blasting cap was detonated. A muffled report was heard and the block blew apart. On observing the results, it was found that two of the blasting caps were still in their proper hole in two large pieces of the block with all the other

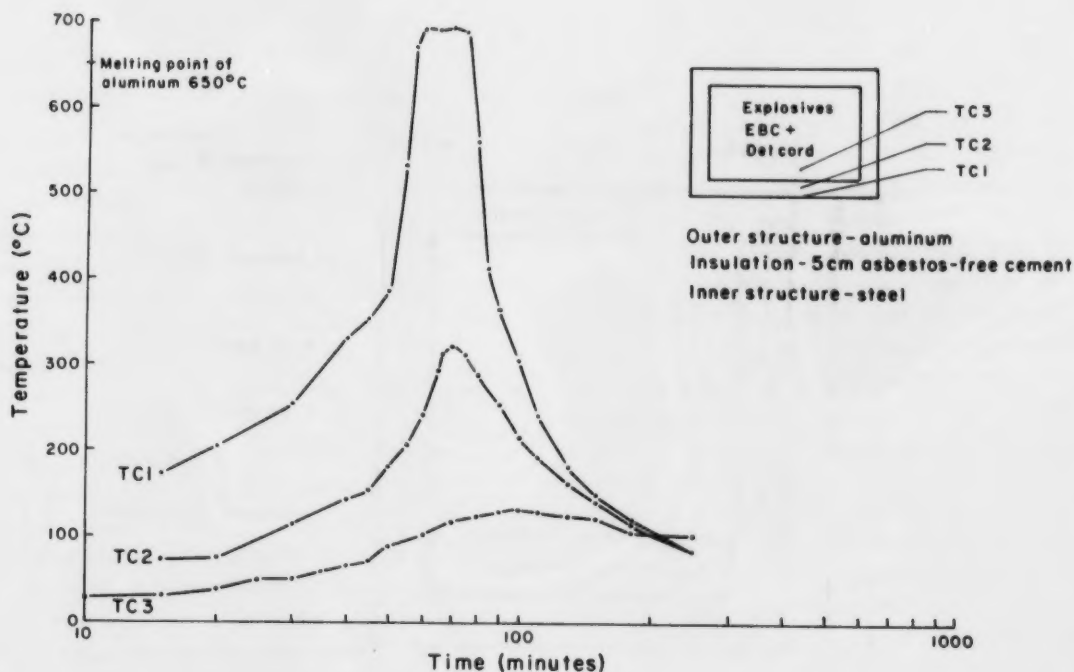


Fig. 10 - Temperature profiles from fire test on container insulated with asbestos-free cement



Fig. 11 - Result of fire test on container insulated with asbestos-free cement

pieces and blasting caps remaining relatively close to their original position. No communication took place. The center blasting cap fragmented the calcium silicate in its vicinity. The fact that the pieces were large and not widely scattered, that the immediate calcium silicate was fragmented to small pieces, that the other blasting caps were not initiated, and that the report was muffled indicates that this substance absorbs a large amount of the blast energy.

In an attempt to improve this system it was decided to test the setup shown in Fig. 13. Three pieces, each 5 cm thick, of calcium silicate were glued together and placed in a 13 cm deep and 13 cm diameter tin container. A 4 cm diameter hole, 10 cm deep was made 1 cm off-centre and in it was placed a piece of foam insulation that is used on residential and commercial water pipes. A high-strength electric blasting cap was placed

Table 1 - Properties of insulating materials

Material	R Value (per 5 cm)	Thermal conductivity (Kcal/m-h-°C)	Density (kg/m ³)	Maximum service temp (°C)
Foamed glass	5.26	0.047	136	-
Calcium silicate (hydrous)	5.40	0.054	208	815
Glass fibre board	8.00	-	48	230
Polystyrene foam	7.94	0.036	27	170
Paper board (wood pulp)	5.95	-	265	-
Vermiculite	5.00	-	64	1300
Asbestos-free cement (vermiculite base)	-	-	900	815
Thermo-cell (asbestos-free cement)	-	-	800	-
- Portland Cement				
- vermiculite				
- diatomaceous earth				

in the 1.5 cm diameter hole in the insulation. With the container on the ground, the blasting cap was initiated. The results are shown in Fig. 14. Again, the calcium silicate pieces were large except for those adjacent to the blasting cap which showed fragmentation. The foam insulation was partly shredded and the can was ripped open at the seam. This is an indication that a large amount of the blast energy was absorbed. Use of the foam insert did not seem to make much difference.

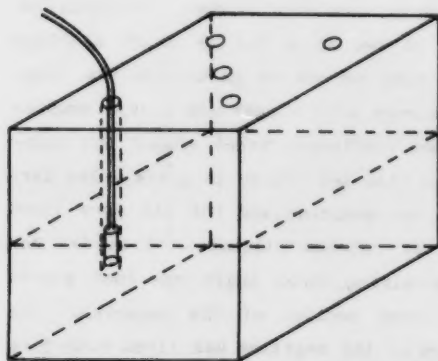


Fig. 12 - Calcium silicate blasting cap container

A 14 cm by 14 cm by 14 cm container was next constructed from 5 cm thick calcium silicate. Inside the container was placed an electric blasting cap and a 15 cm length of detonating cord. The assembled box was then subjected to a fire

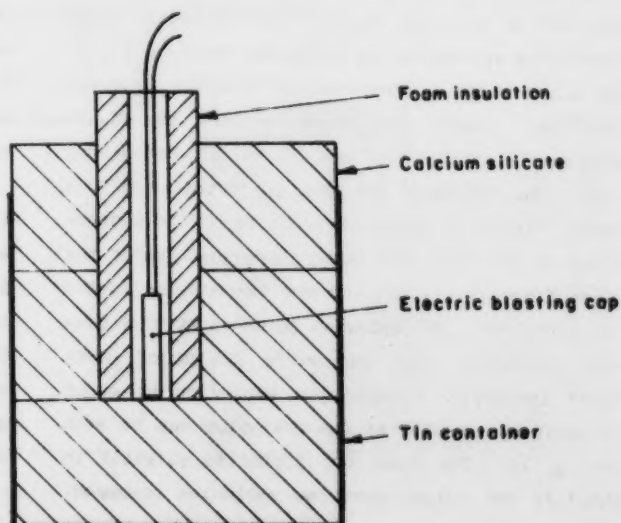


Fig. 13 - Calcium silicate blasting cap container with foam insulation liner



Fig. 14 - Result of test on calcium silicate blasting cap container with foam insulation liner

test. Figure 15 shows the container while Fig. 16 shows the temperature profile of the fire. An explosion took place 38.5 minutes after the start of the fire. Thus, 5 cm of calcium silicate should delay an explosion for at least 30 minutes.

In order to test this insulation in a magazine structure, the steel ammunition box shown in Fig. 17 was first lined with 2.5 cm of rigid glass fibre insulation and then with 5 cm of calcium silicate. The glass fibre insulation placed adjacent to the steel walls of the container would contribute an insulating value and would be a better shock absorber than calcium silicate to rough handling. Inside the magazine were placed an electric blasting cap and 30 cm of detonating cord. The container was then subjected to a fire test. Figure 18 shows the profiles of the temperature of the fire, the temperature just inside the glass fibre insulation and the temperature inside the container. An explosion occurred at 47.9 minutes indicating that the extra 2.5 cm of glass fibre insulation delayed the explosion by about 10 minutes. Results of the explosion can be seen in Fig. 19. The steel box distorted slightly in the fire and bulged when the explosion occurred. However, the lid remained in place (due to the well-designed locks) and there were no metal fragments. Again, there were indications that the in-

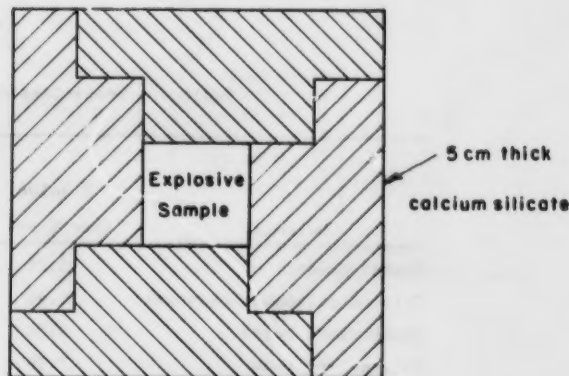


Fig. 15 - Calcium silicate test container

sulation absorbed a large amount of the energy released by the blast.

This container would probably prevent explosions for at least one hour by simply adding more insulation. However, this would reduce the inside volume and since a separate box would also be required for blasting caps, the complete steel magazine would be rather large and heavy. An aluminum box is favoured since it would weigh less, however, there is the problem that aluminum melts in a wood fire. Therefore, if aluminum is to be used for the outside container, provisions must be made for holding the insulation together once the aluminum has melted. Such a container was manufactured and is described below.

Figure 20 shows the magazine manufactured from 1.6 mm thick dimpled aluminum. The container was divided in two by a 4.8 mm thick aluminum plate which also served to guide the two lids. Three steel straps with hinges and clasps mounted on them formed continuous bands around the magazine when the lids are locked in place. The larger side of the magazine and the lid were lined with 7.5 cm of calcium silicate. A wooden box with lid containing three trays was then placed inside the lined section of the magazine. The small section of the magazine was lined with 5 cm of calcium silicate, while the lid was lined as

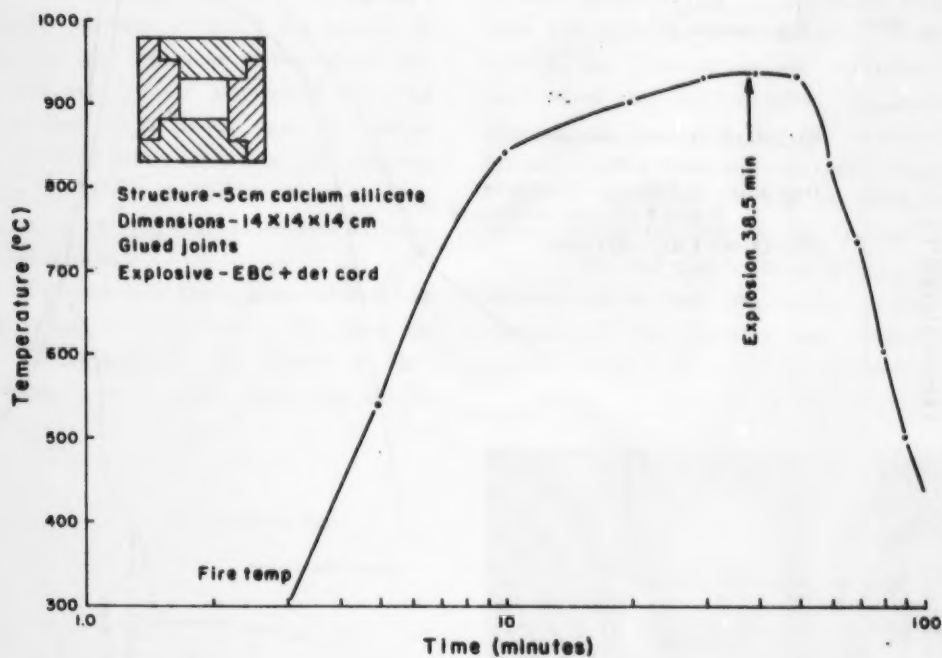


Fig. 16 - Temperature profiles from fire test on calcium silicate test container

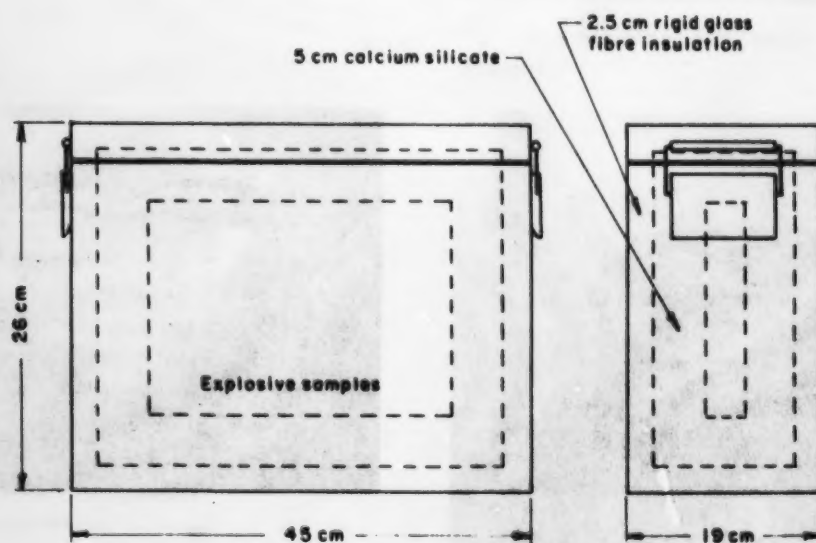


Fig. 17 - Steel ammunition box lined with insulation

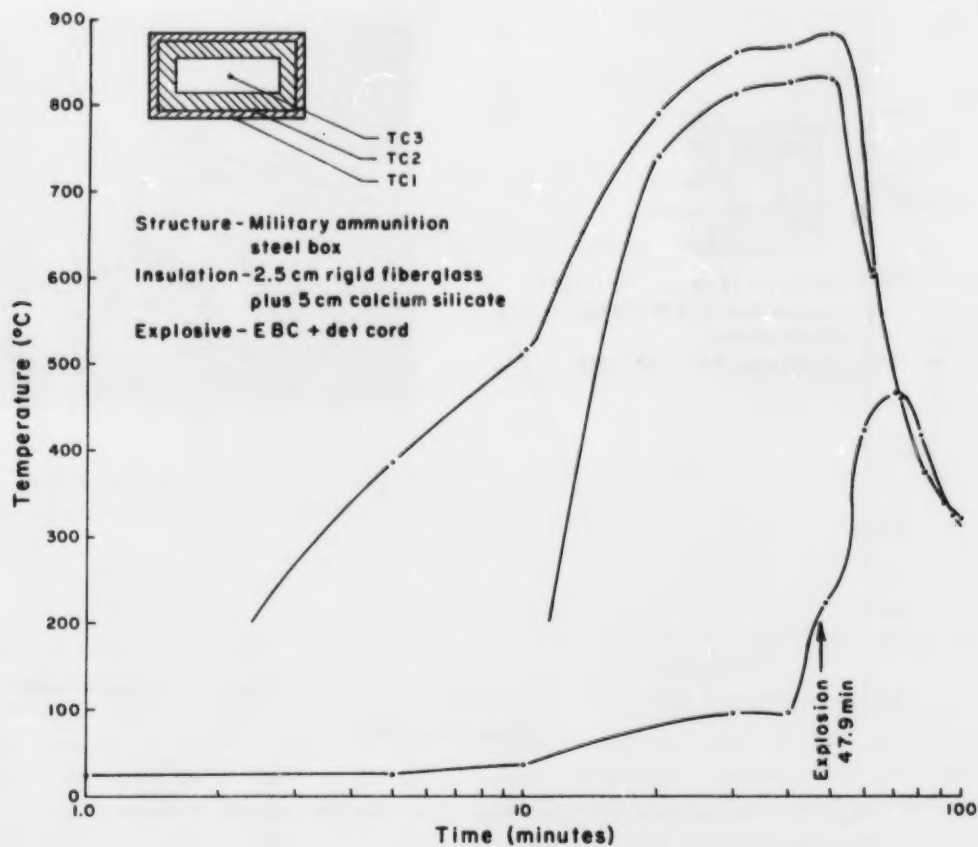


Fig. 18 - Temperature profiles from fire test on the ammunition box

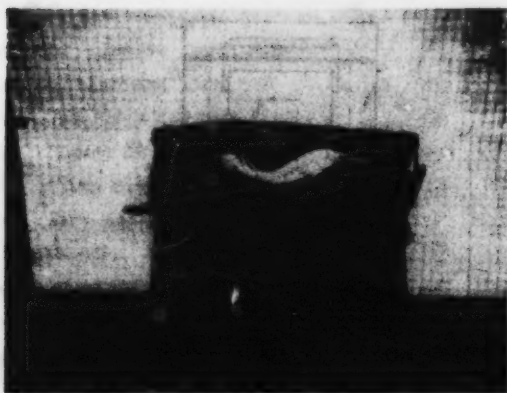


Fig. 19 - Result of fire test on the ammunition box

the other with 7.5 cm of insulation. A calcium silicate block such as the one used earlier for determining shock communication of blasting caps was manufactured so that it would fit snugly in this section of the container. The block was drilled so that each of the ten holes could be lined with a piece of aluminum pipe into which would fit a blasting cap. Space was left between the top of the block and the lid for the electric blasting cap wires and the fuse assemblies of non-electric blasting caps.

The container was first prepared for the blasting cap communication test. As shown in Fig. 21 a sample of explosive was placed in each tray. The three samples were sheet explosive,

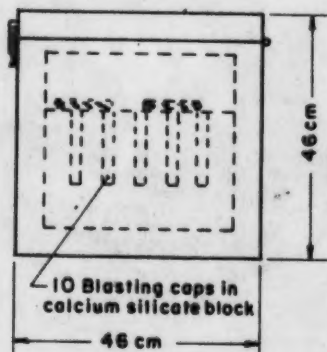
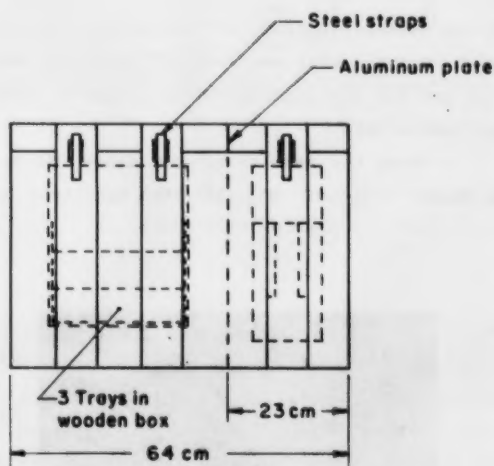


Fig. 20 - Magazine manufactured with dimpled aluminum

detonating cord and Composition C-4. The ten blasting caps were placed in their appropriate holes with one having its leg wires extended outside the magazine (see Fig. 22). With the lids closed, the blasting cap was initiated. The result was a very muffled sound. On inspecting the results, it was found that no communication took place. Figure 23 shows the slight bulge resulting from the explosion and Fig. 24 shows the slight damage inside the blasting cap section of the magazine. The calcium silicate block fractured at several places and fragmented in the immediate vicinity of the blasting cap. Remnants of the

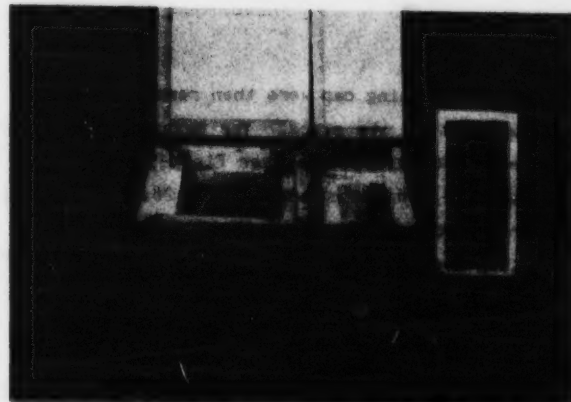


Fig. 21 - Magazine with three trays ready for assembly



Fig. 22 - Magazine ready for communication test



Fig. 23 - Slight bulge of magazine side wall due to communication test

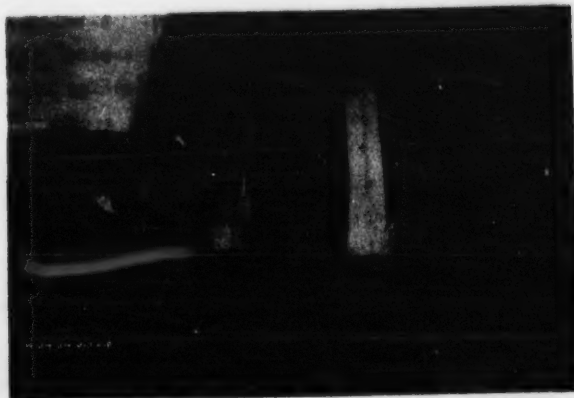


Fig. 24 - Damage to blasting cap compartment due to communication test

detonated blasting cap were then removed and a new one was put in its place. The magazine was then subjected to a fire test (see Fig. 25) having the temperature profile shown in Fig. 26. From this figure, it can be seen that the temperature in the blasting cap compartment did not rise above 100°C in the first 90 minutes. At this time, the blasting caps began to detonate. Since a large section of the outside box was already melted, the detonating blasting caps caused the unsupported insulation to fragment. This was followed by a sharp temperature rise that caused the remaining blasting caps to detonate. Again, from Fig. 26 it is seen that the explosives' compartment was not disturbed by the detonating blasting caps since the rate of temperature rise was unaltered. The temperature rose slowly to 140°C in the first 180 minutes. However, even as the fire temperature was decreasing, the temperature inside the explosives' compartment was increasing, thereby indicating that heat was being generated. That is, the explosive samples and the wooden box and trays were burning. Also, as indicated in Fig. 26, the temperature inside the explosives' compartment was 550°C, 20 hours after the start of the burn.

Figure 27 shows the damage done to the blasting cap compartment. However, note that the steel straps kept the insulation of the explosives' compartment in place even though the alumi-

num has melted. Inside, the insulation was still intact, but all that was left of the three wooden trays and box and explosives was a small pile of very fine ashes.

From the results of the above tests, it was found that not all of the materials were



Fig. 25 - Fire test on dimpled aluminum magazine

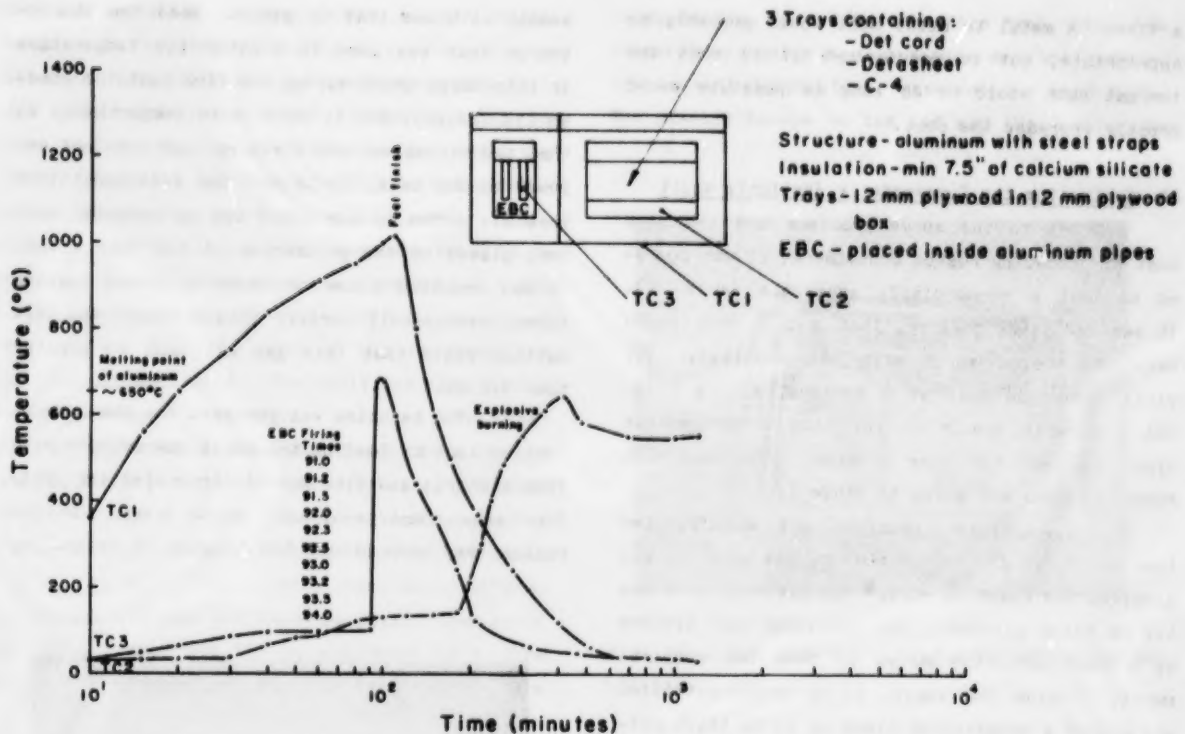


Fig. 26 - Temperature profiles from fire test on dimpled aluminum magazine with calcium silicate insulation

equally useful. As the material for the outside container, the steel is most effective for containment, but the aluminum is lighter. As insulating material, the asbestos-free cement proved to be very effective and is very practical if forming is required. However, calcium silicate is much easier to work with. For an inside container, anything could be used assuming that the insulation protecting it does not fall apart. However, non-metallic materials are preferred for safety reasons.

Even though some of these containers do adhere to the requirements, they are very awkward to use. The main reason for this situation is that to keep the cost low, it is very difficult to manufacture a container that has a functional tight-fitting lid. With the designed containers, when the lid is closed, insulation seals against insulation. Eventually this will wear, but meanwhile the container will always have loose insula-

tion particles. If a protective cover such as wood was placed on the insulation, then there would be a wood to wood seal and precautions would be necessary to prevent the wood from burning in



Fig. 27 - Damage resulting from fire test

a fire. A metal to metal seal would probably be appropriate, but to manufacture it so that the thermal path would be as long as possible would greatly increase the cost.

d) Evaluating the Commercially Available Vault

Due to the above problems and the high cost of producing custom containers, it was decided to test a commercially available vault (4). It was realized, however, that such a unit would have its weight as a major disadvantage. The vault chosen is sold as a vertical filing unit, has a plastic handle on the lid, a paracentric type lock and two side handles. The remaining specifications are given in Table 2.

A separate container was manufactured that would fit in the vault and would hold the explosives and blasting caps. The material used was 1.2 cm thick plywood. The container was divided by a wood partition so as to form two compartments. Inside the small, 13 cm wide, partition was placed a snugfitting block of 15 cm thick calcium silicate, and it was covered by a piece of plywood that was nailed in place. Ten holes 9.5 mm in diameter were drilled through the plywood and 11 cm deep into the calcium silicate block. The hole centres were 4.2 cm from each other and from the edge of the block. Any combination of ten electric and non-electric blasting caps could be placed in the holes in this compartment.

Three trays manufactured from the same plywood were made so that they could be stacked in the large compartment. Figure 28 shows the as-

sembly with one tray in place. Note the thermocouple that was used to monitor the temperature in this compartment during the fire test. A wooden lid was provided to cover both compartments so that the explosives and blasting caps were not exposed to any metal surfaces. One additional item that was added to the vault was an asbestos cord seal placed on the perimeter of the door frame. It was required since the door to frame spacing seemed excessively large. (Manufacturer specifications state that this gap will not be greater than 3.2 mm.)

The magazine was prepared for the communication test by loading the small compartment with five electric and five non-electric blasting caps. The large compartment was loaded next. In the bottom tray were placed two lengths of detonating

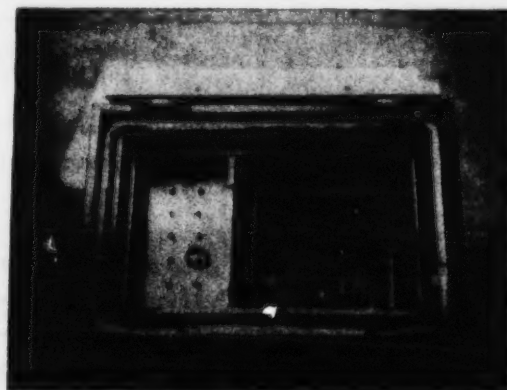


Fig. 28 - Wooden tray in place

Table 2 - Commercially available vault specifications (4)

Outside dimensions	36.8 cm high x 50.4 cm wide x 31.8 cm deep
Inside dimensions	25.4 cm high x 40.6 cm wide x 24.1 cm deep
Weight	36 kg
Side handles	2
Lock	paracentric type
Construction	double electrically welded steel plates
Insulation	Thermo-Cel (cast)

cord and a piece of lead-lined linear shaped charge. In the middle and top tray were placed a piece of sheet explosive and a sample of Composition C-4 respectively. The loaded magazine is shown in Fig. 29. For the communication test, the electric blasting cap placed in the hole indicated in Fig. 28 was the one that was initiated. Thus, with the wooden lid in place and the vault door locked, the said blasting cap was detonated. Via a video monitor, a very small puff of smoke was seen to rise from the edge of the lid when the blasting cap detonated. The vault was then opened and observations were made. None of the other blasting caps had been initiated and there was no damage to the partition. The only visible damage was done to the piece of plywood nailed to the top of the calcium silicate. It had been lifted about 3 cm at one side. Having made these observations, the wooden lid was put back in place, the vault was again locked and it was subjected to a fire test. The temperature profiles of this test are

shown in Fig. 30. After the fire test, when the temperature inside the container was the same as the ambient temperature, observations were made. The plastic handle on the lid and the tumbler in

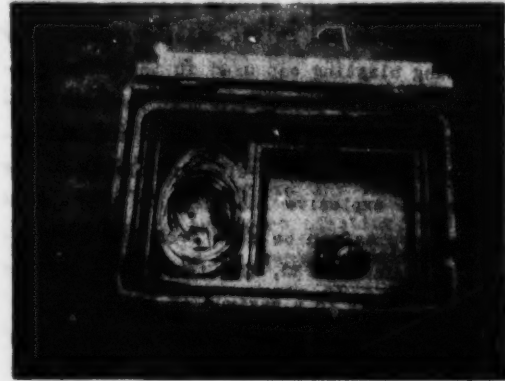


Fig. 29 - The magazine loaded with explosives and blasting caps

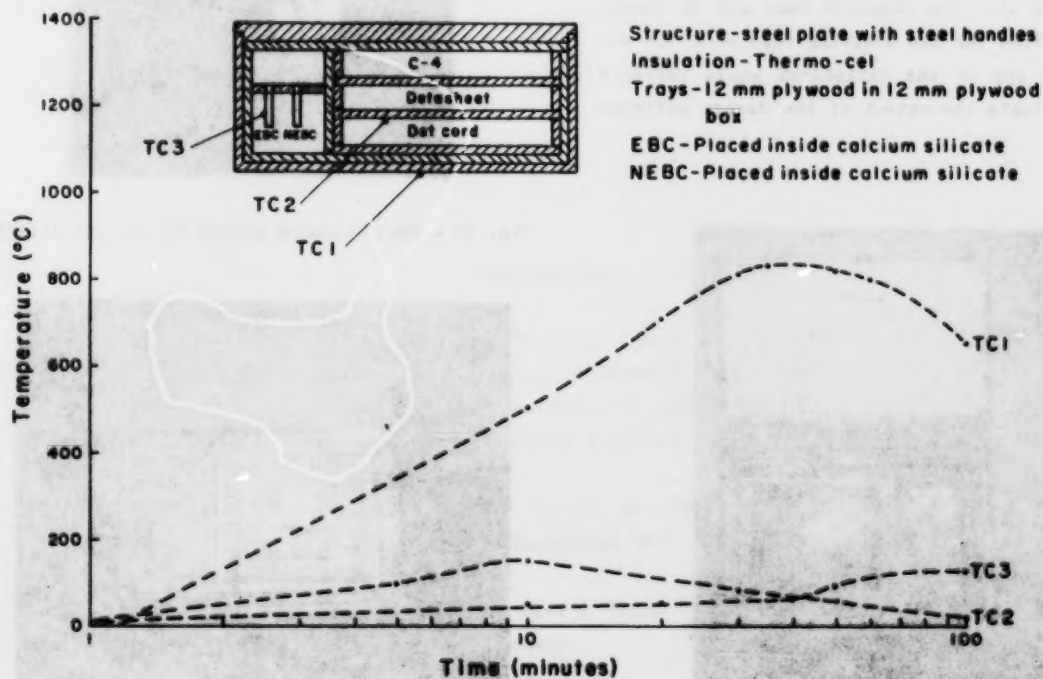


Fig. 30 - Temperature profiles from fire test on commercially available vault

the lock had completely melted so that it was impossible to insert the key in the lock. Using a metal bar, the lock was carefully opened. The inner wooden lid was fully intact and so were the contents. Figure 31 shows the vault with the contents removed, while Fig. 32 shows the vault with the plywood covering the calcium silicate removed. Note the void produced in the calcium silicate by the exploding blasting cap used in the communication test. The only indication that the explosives had been subjected to heat was the discolouration of the fuse of the non-electric blasting caps and the sheet explosive sticking to the wooden tray. However, as can be seen from the temperature profiles in Fig. 30, the temperature inside the vault rose only to a maximum of 125°C.

Seeing that this container survived the fire test rather well, it was decided to submit it to a further test. Again, the lower tray, the middle tray and the top tray were loaded with detonating cord, sheet explosive and Composition C-4 respectively. A new calcium silicate block was manufactured and ten electric blasting caps were inserted in it. The proposed test was to simultaneously fire the ten blasting caps so as to determine if any of the explosives would initiate and to evaluate the extent of the damage suffered

by the container. Since the lock had been damaged, the vault door was held shut by a 140 kg weight. On firing the caps, there was just a small puff of smoke. Figure 33 shows the contents of the vault after firing the caps. The piece of plywood on top of the calcium silicate block had been lifted and there was no damage done to the top tray and its contents. The middle tray and its contents were also still intact. Figure 34 shows the bottom tray and the blasting cap compartment with part of the calcium silicate removed. From the damage to the calcium silicate,



Fig. 31 - Vault with contents removed

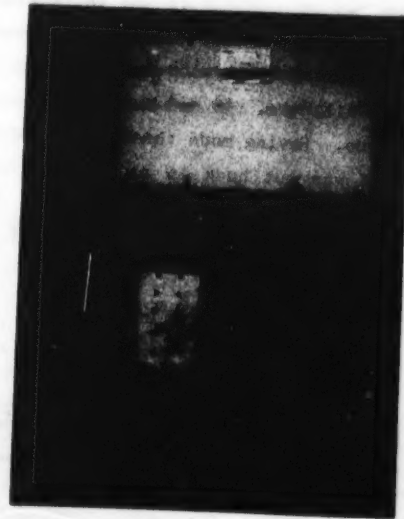


Fig. 32 - Vault showing damage to calcium silicate



Fig. 33 - Vault with contents after simultaneous detonation of ten electric blasting caps

it seems that the simultaneous detonation of the blasting caps basically caused the calcium silicate block to be severed in two. The escaping gases forced the sides of the wooden inner container out, causing the partition to separate and collapsing one of the sides of the bottom tray. However, as seen from Fig. 34, the detonating cord is intact. As designed, the container functioned well.

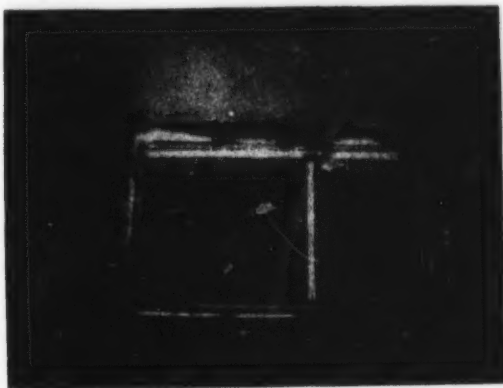


Fig. 34 - Vault after simultaneous detonation of ten electric blasting caps

CONCLUSIONS

From the requirements outlined in the introduction and the fact that custom-made containers are very expensive, the commercially available vault seems to be the best choice. Such containers are easily available at moderate cost and will usually have the Underwriters' Laboratory Class 350 label certifying that they are built to pass defined fire, explosion and impact tests. From the safety point of view, it is best to line the steel vault with a wooden inner box so that the contents are not exposed to any metal surface. Also, in order to transport blasting caps, they must be stored so as to prevent communication to other explosives in the case of a blasting cap detonating. The best method to do this is to use a calcium silicate block as that defined herein.

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3. Foster adhesive 81-27, Mulco Incorporated, Montreal, P.Q., Canada.
4. Vault used was model VC-9K made by Meilink, Whitehouse, Ohio, U.S.A.